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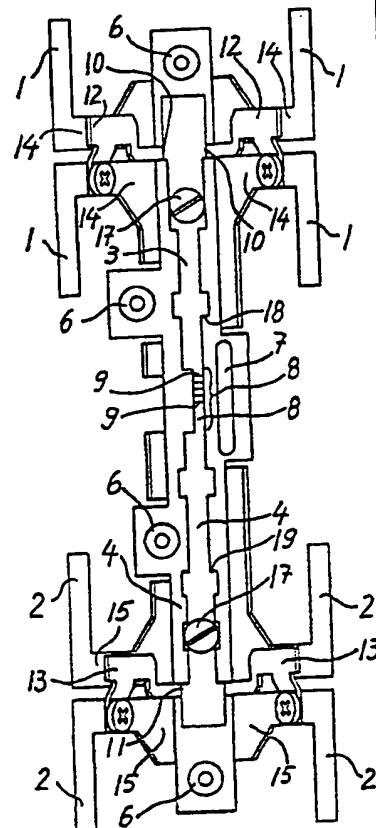
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: AN ANTENNA DEVICE WITH TWO RADIATING ELEMENTS HAVING AN ADJUSTABLE PHASE DIFFERENCE BETWEEN THE RADIATING ELEMENTS

## (57) Abstract

Antenna devices, including a pair and larger arrays of radiators, wherein each pair is to be connected to a first transmission line having a first characteristic impedance  $Z_1$ . Each pair includes at least first and second radiating elements (1, 2) and first and second impedance transformers (3, 4) for the first and second radiating elements. One side of each transformer is connected to the respective element. The other sides are inter-connected by a second transmission line (8) to which their impedances are matched. The second transmission line has a resistive first impedance  $R_1$  equal to twice the first characteristic impedance  $Z_1$ . The first transmission line is to be connected to the second transmission line at a selected one of many possible contact points (9). The selected contact point then determines a signal phase difference between said first and second radiating elements.



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AN ANTENNA DEVICE WITH TWO RADIATING ELEMENTS HAVING AN  
ADJUSTABLE PHASE DIFFERENCE BETWEEN THE RADIATING ELEMENTS

FIELD AND BACKGROUND OF THE INVENTION

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The present invention relates to a radio communication antenna device with two radiating elements or groups of radiating elements, the signal phase difference of which is adjustable. More specifically the invention relates to an antenna device  
10 with two radiating elements or groups of radiating elements interacting to produce a directional radiation beam, the direction of which being adjustable through adjusting said phase difference. The invention may even be applied to direct beams from omni-directional or 360° radiating elements.

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PRIOR ART

In directional beam antenna devices in, e.g., a cellular telephone system it may be desirable to use antennas which may  
20 be adjusted to or pre-set at a specific beam direction or tilt in order to make an efficient use of radiated energy and to provide efficient reception of incident radiation. A mechanical/geometric adjustability of the antenna means is known in the prior art, but, in the case of a multi-radiator  
25 antenna device, an electrical adjustability is more suitable with regard to, e.g., steady mounting of the antenna device. However, electrically adjustable prior art devices require a rather complicated design and permits small variations only in the manufacture and assembly of the antenna device. An  
30 electrically adjustable beam antenna device is disclosed in Patent Abstracts of Japan relating to Japanese Patent Application No. 63-134241. That device includes means for varying delays in feed lines to different radiating elements in an array.

35

SUMMARY OF THE INVENTION

It is a main object of the invention to provide an antenna

device according to the introductory portion of claim 1, wherein an electrical adjustability is achieved and the number and/or lengths of connecting cables/feed transmission lines is reduced. The reduction of the number of cables generally leads to a smaller required number of transformer housings as well. Another object is to reduce the number of components of the antenna device by integration of components. Another object is to provide a mechanically durable and electrically well-defined antenna device. Another object is to provide (identical or a pre-defined set of) modular antenna devices that may be assembled into a variety of antenna configurations exhibiting different parameters and performances. Another object is to provide an antenna device suitable for radio communication, e.g., cellular telephone systems operating at ultrahigh frequencies or higher, where great care in component selection and placement is required. An antenna device with a combination of the above features is more efficient regarding materials, manufacture, and assembly than prior art antenna devices.

These and other objects are attained in an antenna device according to the characterizing portion of the appended claims. In fact only half the number or less of feed transmission lines is required in the antenna device of the invention compared to prior art antenna devices. Below, details and advantages of the present invention will be mentioned and/or further explained.

The first and second radiating elements may, as indicated, consist of more than one radiating element, respectively. Each of the first and second radiating means may consist of a group of radiating means. A signal in the radiating elements of such a group are preferably in phase with each other, but may differ in phase for various interaction effects.

Although described as having one first and one second radiating element, or element groups, it may be advantageous to arrange two or more of the antenna device of the invention, or other radiating elements, in order to obtain interaction resulting in, e.g., a more concentrated radiation beam with a longer

range. The principles of arranging a multi-radiator antenna device are known per se, but the antenna device of the invention offers great improvement as outlined above.

- 5 The antenna device is to be connected via the first transmission line to a radio transmitting and/or receiving device in a well-known manner. However the connection between the first transmission line and the second transmission line is important in the antenna device of the invention. This connection constitutes substantially a pure current division, since the first transmission has half the characteristic impedance of the second transmission line. Thus the energy of a signal propagating in the first transmission line toward the contact point is split in equal halves propagating in each direction from the contact point in the second transmission line, vice versa.

20 This implies that the choice of contact point effects substantially the length of the signal path only from the contact point to the respective radiating element (or group of radiating elements). Apparently, there is a linear relationship between the position of the contact point on the second transmission line and the phase difference between the signal phase in the radiating elements.

- 25 As a borderline case, in order to obtain a largest possible phase difference between the first and second radiating elements, the connection point for the first transmission line may be selected slightly outside a portion of the second transmission line, which portion has a substantially constant and resistive characteristic impedance. Although matching, phase and power-splitting properties will vary outside that portion, in the direction of one of the radiating elements, it would thus be possible to make such a selection of the contact point. However, to some extent that would lead to deterioration in antenna performance.

The conductive ground means (reflector), which may be a

continuous metal plate ground plane, has a predetermined orientation and position in relation to the first and second radiating elements in order for the radiating elements to give well-defined beam direction and radiation element impedance properties.

The first and second impedance transformer means perform matching of the impedance of the radiating element, in combination with the balun means wherever applicable, to the impedance of the second transmission line.

Each impedance transformer may be formed by a first elongated (possibly including curves or bends) conductive element (possibly formed by part of said conductive ground means) and, extending alongside thereof or substantially parallel thereto and separated from it, a second elongated conductive element, together defining sections with different characteristic impedance along their extension.

The second conductive element comprising a step in cross-sectional dimensions between two adjacent sections so as to obtain a change of characteristic impedance. The change in characteristic impedance may also be achieved through a change of a dielectric between the conductive elements.

The second conductive element may comprise a step in cross-sectional dimensions between two adjacent sections so as to obtain a change of characteristic impedance.

The second transmission line may be formed by a third elongated (possibly including curves or bends) conductive element (possibly formed by part of said conductive ground means) and, alongside thereof or substantially parallel thereto and separated from it, a fourth elongated conductive element.

The second transmission line may have a curved (arced) path in a plane perpendicular to the first transmission line partly encircling one conductor of the first transmission line.

The radiating elements of the antenna device or group of antenna devices may be arranged in an substantially plane and orthogonal matrix with a radiator center-to-center distance in one dimension being approximately one wavelength or less, 0.9-1.0 wavelengths being a preferred value range.

The first and second radiating element, the first and second transformers, and the second transmission line may together form one structural unit mounted on the conductive ground means.

The first and third connecting means of the first impedance transformer may be coupled via a first and second balun means to the first and second radiating elements, respectively.

The radiating elements and/or the elongated conductive elements may be comprised of single metal plate element(s).

The second transmission may be provided with marks indicating possible positions of the contact point each giving a predetermined phase difference in the signal between the first and second radiating elements.

The second transmission line may have at least an electrical length of substantially equal to or less than one eighth of a wavelength.

The radiating elements may advantageously be oriented in the same direction (of polarization or phase).

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a top view of an antenna device according to the invention mounted on a ground plane (not shown) and to be connected to a first transmission line, including two groups of radiating dipole elements, balun means, impedance transformers, and a second transmission line, formed from essentially two formed metal plate elements.

Fig. 2 shows a first side view of the antenna device of fig. 1.

Fig. 3 shows a second side view of the antenna device of fig. 1 indicating also the ground plane on which the antenna device is mounted.

Fig. 4 shows a perspective view with a cut-away section and a partial enlargement of another antenna device according to the invention to be connected to a first transmission line, including a ground plane, two radiating microstrip patch elements on a substrate parallel to and spaced from the ground plane, impedance transformers, and a second transmission line.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

With reference to figs. 1-3 an antenna device is described having two first radiating dipole means 1, fed in phase and separated by less than one half wavelength and being parallel to each other, and two second radiating dipole means 2, fed in phase and each being oriented aligned with a respective one of the first radiating elements 1 at a center-to-center distance in the order of one half wavelength. Each dipole 1, 2 has a length of approximately one half wavelength and is oriented parallel to a conductive ground plane reflector 5 at a distance of approximately one quarter of a wavelength.

The first and second radiating elements 1, 2 are fed from a first and second impedance transformers 3, 4, via first and second balun means 12 and 14, 13 and 15, respectively. The first and second impedance transformers are interconnected by a second transmission line 8.

The dipoles 1, 2, parts 14, 15 of the balun means, and signal ground conductors of the impedance transformers 3, 4 and the second transmission line 8 are formed (punched) from one first metal plate constituting a bottom portion of the antenna device. This bottom portion is provided with relatively low downwards projecting warts 6 which are fastened to the



reflector 5 with screws and nuts (not shown) for well-defined electrical contact points, adjacent ones of which are to be separated by less than one half wavelength.

- 5 Parts 12, 13 of the balun means, signal transmitting parts of the impedance transformers 3, 4, and of the second transmission line 8 are formed by one second metal plate constituting a top portion of the antenna device fastened to a lower part of the bottom portion and, parallel to and spaced from the bottom
- 10 portion, by non-conductive fastening elements 17 and at the balun means with conductive fastening means. To be advantageous in large scale manufacturing, the second plate may be produced by punching.
- 15 The upper part of the first and second impedance transformers 3, 4 have widths varying in steps 18, 19, respectively, along their extension providing different characteristic impedance in sections, which allow an effective impedance match between the balun means, connected to the antenna, and the second
- 20 transmission line 8, having a characteristic impedance of 100 ohms. A first transmission line (not shown) to be connected to the antenna means is a 50 ohms coaxial line. It is to be mounted in a grounding and fastening block (not shown) that can be fasten and grounded at any point along a slot 7 in the
- 25 bottom portion. The center conductor of the coaxial line is to be soldered at any position along the upper part of the second transmission line 8, that position determining the phase difference of the signal at the first and second radiating elements 1, 2. There are marks 9 on the second transmission
- 30 line 8 for guiding in the selection of an intended phase difference.

Further antenna devices of the type shown in figs. 1-3 may be arranged (in a matrix) on the same ground plane (reflector) to

35 interact with the radiators of the first antenna device similarly to the way these interact with each other.

With reference to fig. 4 an antenna device is described formed

by partly microstrip printed circuits on a plane non-conductive substrate 42 including a first radiating patch element 31 fed at 40 by a first impedance transformer 33, 43 connecting and matching the first patch element 31 to an arced transmission line 38 of 100 ohms connected to a second impedance transformer 34 that matches the second transmission line 38 and a second radiating patch element 32 connected at 41, a second radiating patch element 32 oriented in a mirror-like fashion in relation to the first radiating patch element 31, partly a conductive reflector 35 supporting the substrate 42 on equal separating and fastening means 46, 47. A coaxial feed line is entered perpendicularly to the substrate and is contacted to the second transmission line via its center conductor 36 and a segment 37 to a point 39 determining the phase difference, all in a similar way to what is said above. For clarity fig. 4 includes a cut-away portion 44 and an enlarged portion 45.

## CLAIMS

1. An antenna device to be connected to a first transmission line with a first characteristic impedance  $Z_1$ , said antenna device comprising:
- at least one first radiating element;
  - at least one second radiating element;
  - a first impedance transformer means having first and second connecting means, said first connecting means being coupled to said first radiating element;
  - a second impedance transformer means having third and fourth connecting means, said third connecting means being coupled to said second radiating element, characterized by
  - said first impedance transformer means at said second connecting means and said second impedance transformer means at said fourth connecting means exhibiting a substantially equal and substantially resistive first impedance  $R_1$  being substantially equal to twice said first characteristic impedance  $Z_1$ ;
  - said second and fourth connecting means being interconnected by a second transmission line with a second characteristic impedance  $Z_2$  being substantially equal to said first impedance  $R_1$ ;
  - said first transmission line being to be connected to said second transmission line at a contact point determining a signal phase difference between said first and second radiating elements.
2. An antenna device according to claim 1 or any of the dependent claim(s), characterized by said antenna device further comprising a conductive ground means, said first radiating element having a predetermined separation from said conductive ground means and said second radiating element having a predetermined separation from said conductive ground means.
3. An antenna device according to claim 1 or any of the dependent claim(s), characterized by each

impedance transformer being formed by a first elongated conductive element and, alongside thereof and separated from it, a second elongated conductive element, together defining sections with different characteristic impedances along their extension.

5  
10 4. An antenna device according to claim 1 or any of the dependent claim(s), characterized by said second transmission line being formed by a third elongated conductive element and, alongside thereof and separated from it, a fourth elongated conductive element.

15 5. An antenna device according to claim 1 or any of the dependent claim(s), characterized by said second transmission line having a curved path in a plane perpendicular to said first transmission line partly encircling one conductor of said first transmission line.

20 6. An antenna array composed by at least one antenna device according to claim 1 or any of the dependent claim(s), characterized in said radiating elements of said antenna device(s) being arranged in an substantially plane and orthogonal matrix with a center-to-center distance in one dimension being in the order of one wavelength.

25  
30 7. An antenna device according to claim 1 or any of the dependent claim(s), characterized by said first and second radiating element(s), said first and second transformers, and said second transmission line together forming one structural unit mounted on said conductive ground means.

35 8. An antenna device according to claim 1 or any of the dependent claim(s), characterized by said first and third connecting means of said first impedance transformer being coupled via a first and second balun means to said first and second radiating element(s), respectively.

9. An antenna device according claim 1, c h a r a c t e -  
r i z e d i n said radiating elements and/or said elongated  
conductive elements being comprised of a single metal plate  
element(s).

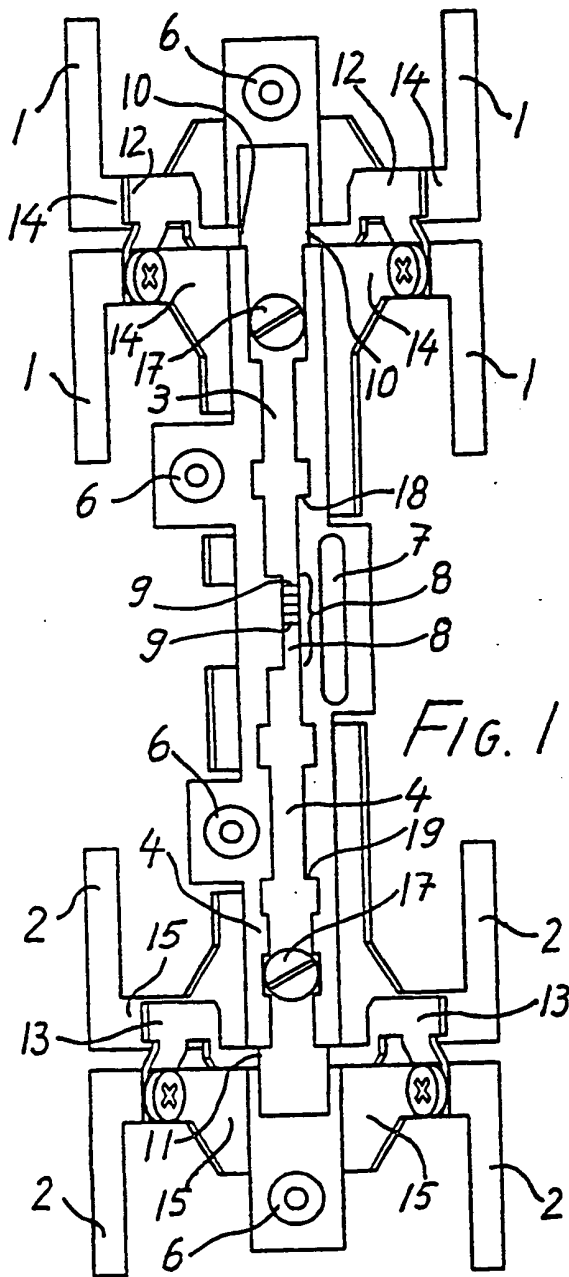


FIG. 1

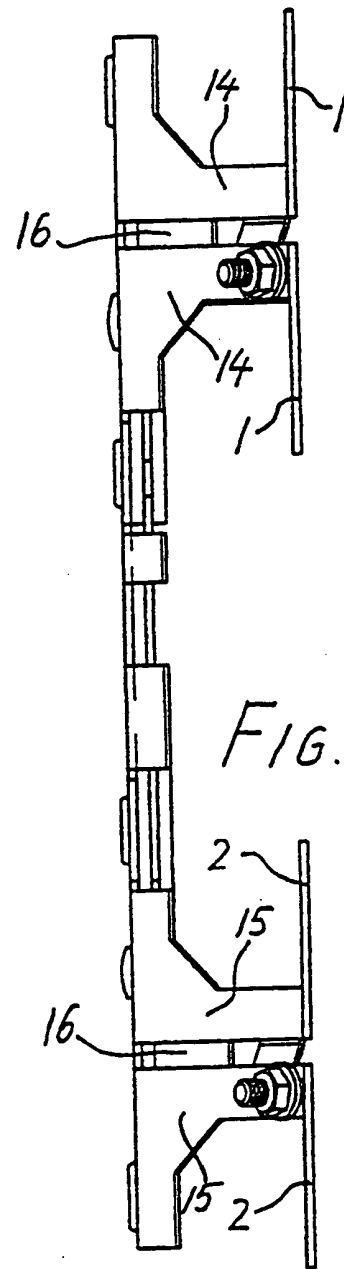


FIG. 2

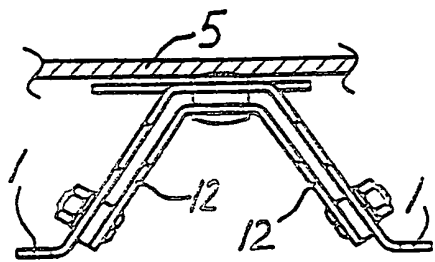


FIG. 3

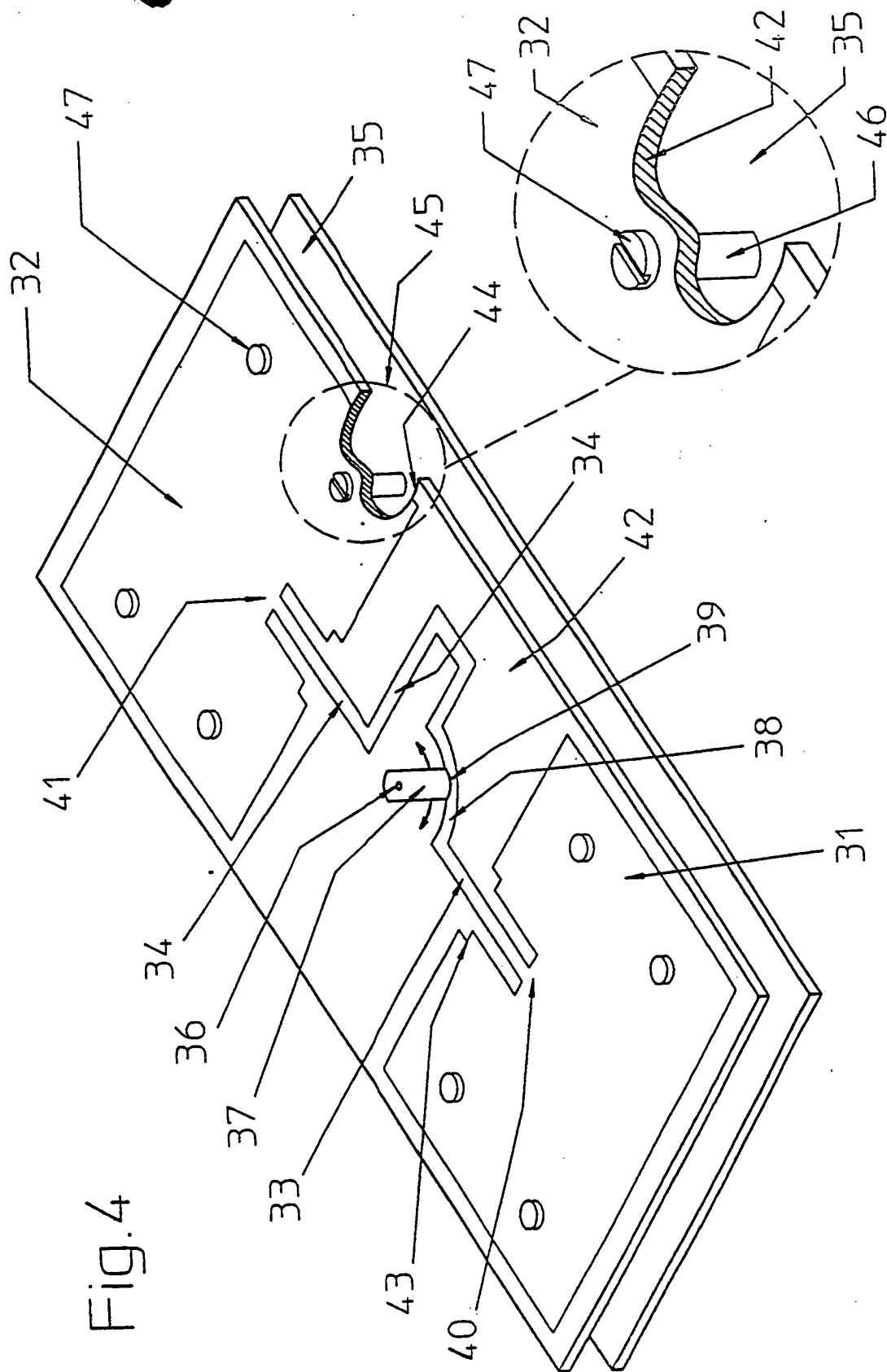


Fig. 4

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT 96/00627

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01Q 3/34  
According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## WPI, CLAIMS

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4427984 A (ROY E. ANDERSON), 24 January 1984 (24.01.84), column 2, line 54 - column 4, line 63, figures 1,2,3, abstract	1-9
A	US 3611400 A (TOKYO SHIBAURA ELECTRIC CO., LTD.), 5 October 1971 (05.10.71), column 2, line 70 - column 4, line 70, figures 5-7, abstract	1-9
A	US 4713670 A (TOSHIO MAKIMOTO ET AL), 15 December 1987 (15.12.87), column 2, line 50 - column 3, line 64, figures 1,2, abstract	1-9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

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International application No.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4427984	24/01/84	NONE	
US-A- 3611400	05/10/71	DE-A- 1952212 GB-A- 1297153	30/04/70 22/11/72
US-A- 4713670	15/12/87	DE-A,A,C 3601649 FR-A- 2578105 GB-A,B- 2170051 JP-A- 61167203	24/07/86 29/08/86 23/07/86 28/07/86